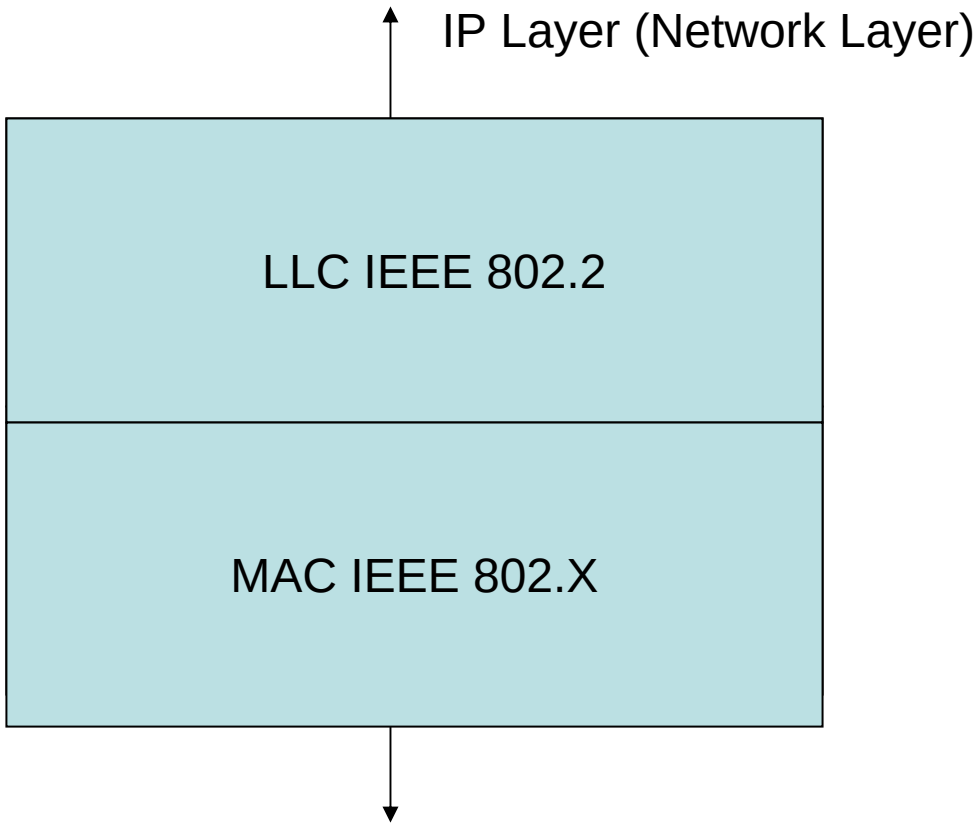
Link Layer Standards and Protocols

Link Layer Standards



Medium Access Control Layer Services

- Concerned with the following
  - Channel allocation
  - Random backoff during collision
  - Prioritizing
  - Error detection
  - Framing
  - E.g., Ethernet, Token Ring, Wi-Fi
- MAC layers are typically connectionless and unreliable
  - Except where the medium is problematic E.g.Wi-Fi

Logical Link Control Services

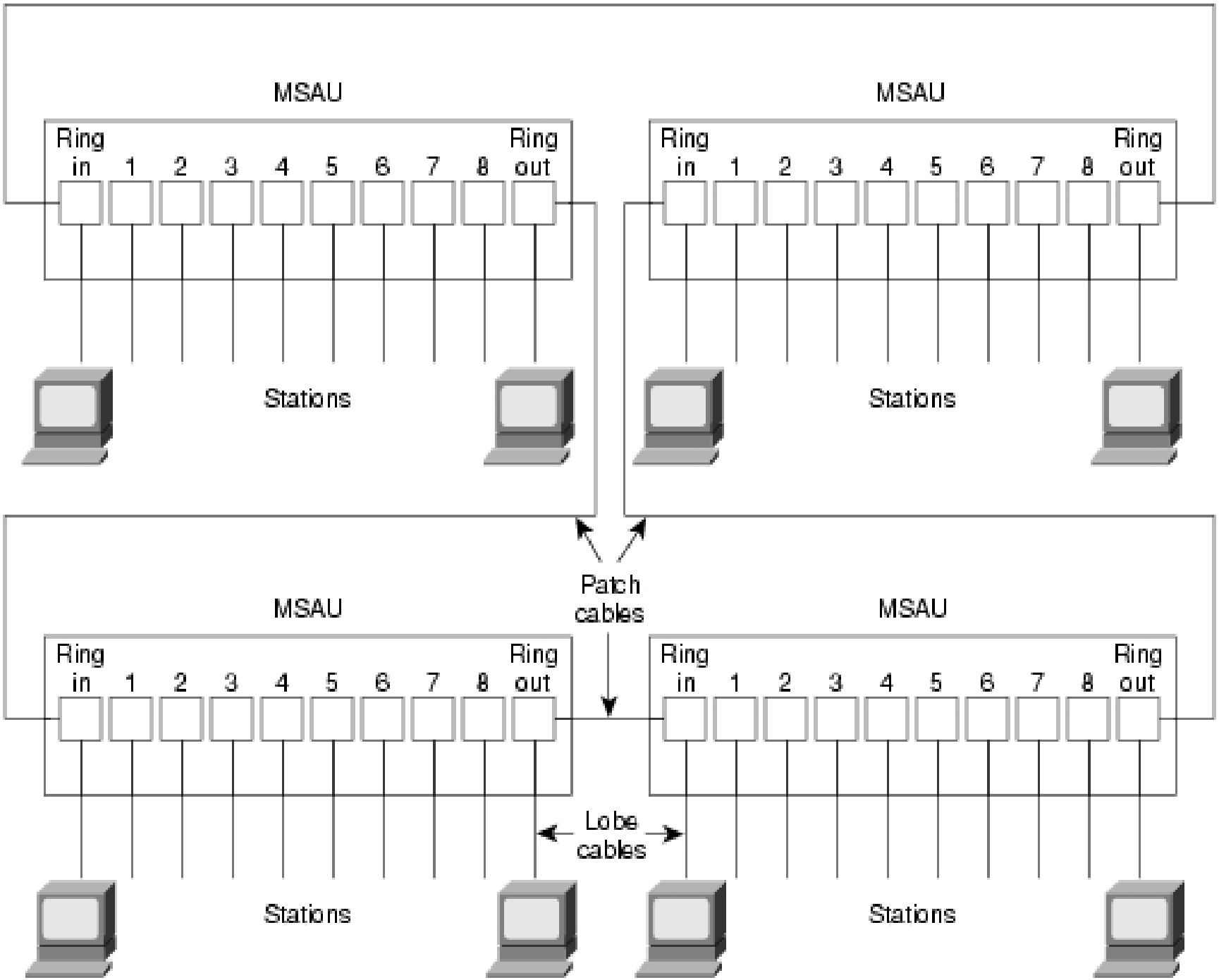
- MAC layer is best-effort. Additional features can be introduced via LLC. IEEE 802.2 committee defines three types of LLC
  - Type 1: datagram protocol, best-effort
  - Type 2: connection-oriented on basic datagram
    - Sequence numbering, piggybacked acks, differentiate control from data packets
    - Connection-management as required in point-to-point links E.g. PPP
  - Type 3: semi-reliable protocol, provides acknowledgements with connection-less service

Standard Link Layer Protocols

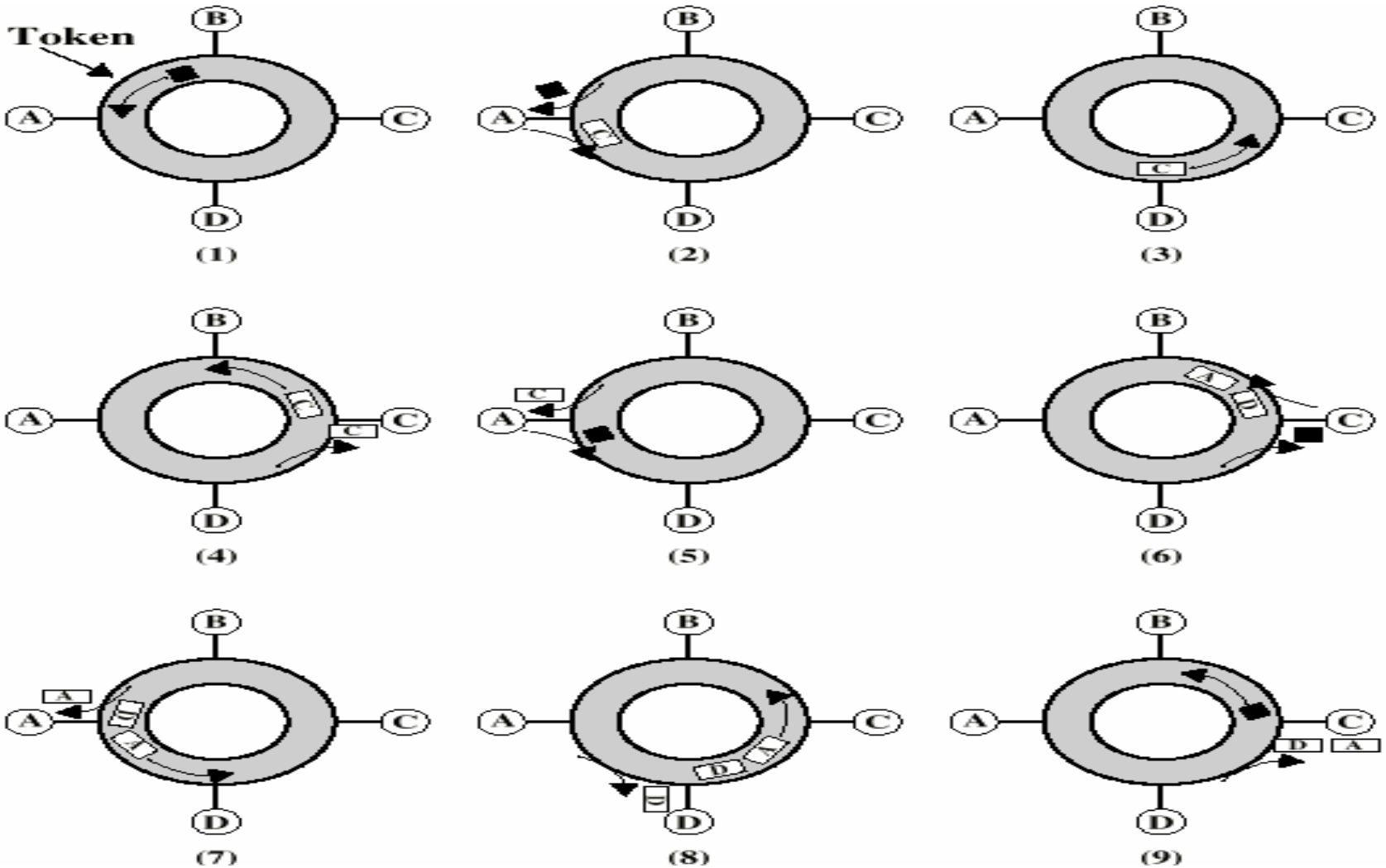
- Ethernet (IEEE 802.3)
- Token Ring (IEEE 802.5/IBM)
- FDDI (ANSI X3T12)
- Wireless
  - Wi-fi (802.11x)
  - Wi-Max (IEEE 802.16)
  - Bluetooth
  - UWD
  - Gigabit wireless
- HDLC
- PPP

IEEE 802.5/IBM Token Ring

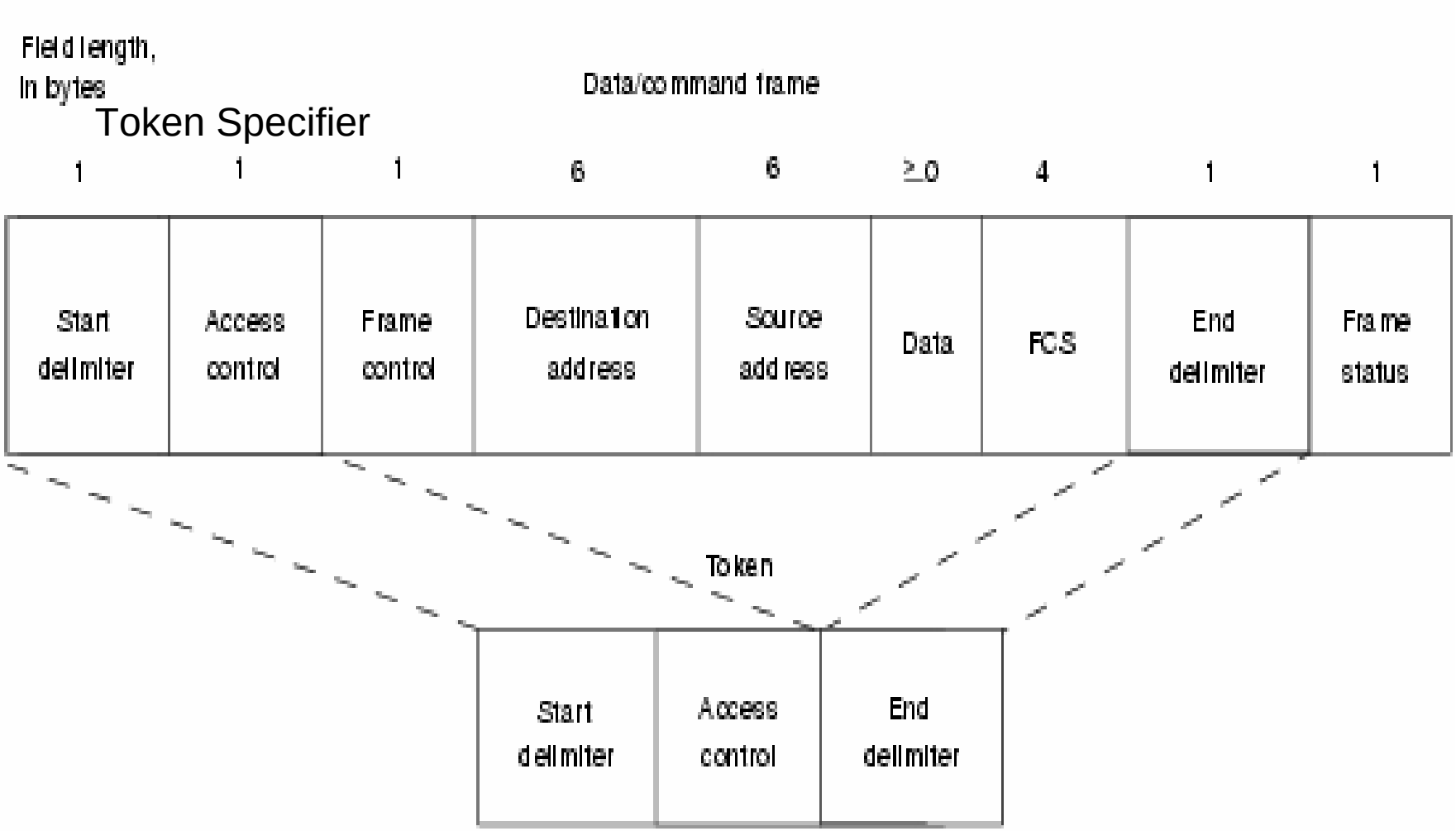
- The stations form a logical ring (star-wired-ring network)
  - Small frame (token) circulates when idle
  - Only the possession of a token allows a node to transmit
  - Upon possession, a sending station changes one bit in token to make it SOF for data frame
  - Appends rest of data frame to the token
  - Frame makes round trip, reaches destination and is finally absorbed by transmitting station
    - sending station can perform some checks to see if frame was received correctly by the destination node
  - Sending station then inserts new token when transmission has finished and leading edge of returning frame arrives
  - Token rings give deterministic access and delay is deterministic
    - They are used in applications where predictable delay and robustness of network is needed


MSAU
MSAU
Ring in
1
2
3
4
5
6
7
8
Ring out
Stations
Stations
Patch cables
MSAU
MSAU
Lobe cables
Stations
Stations

Token Ring Operation



Token Ring MAC Frame

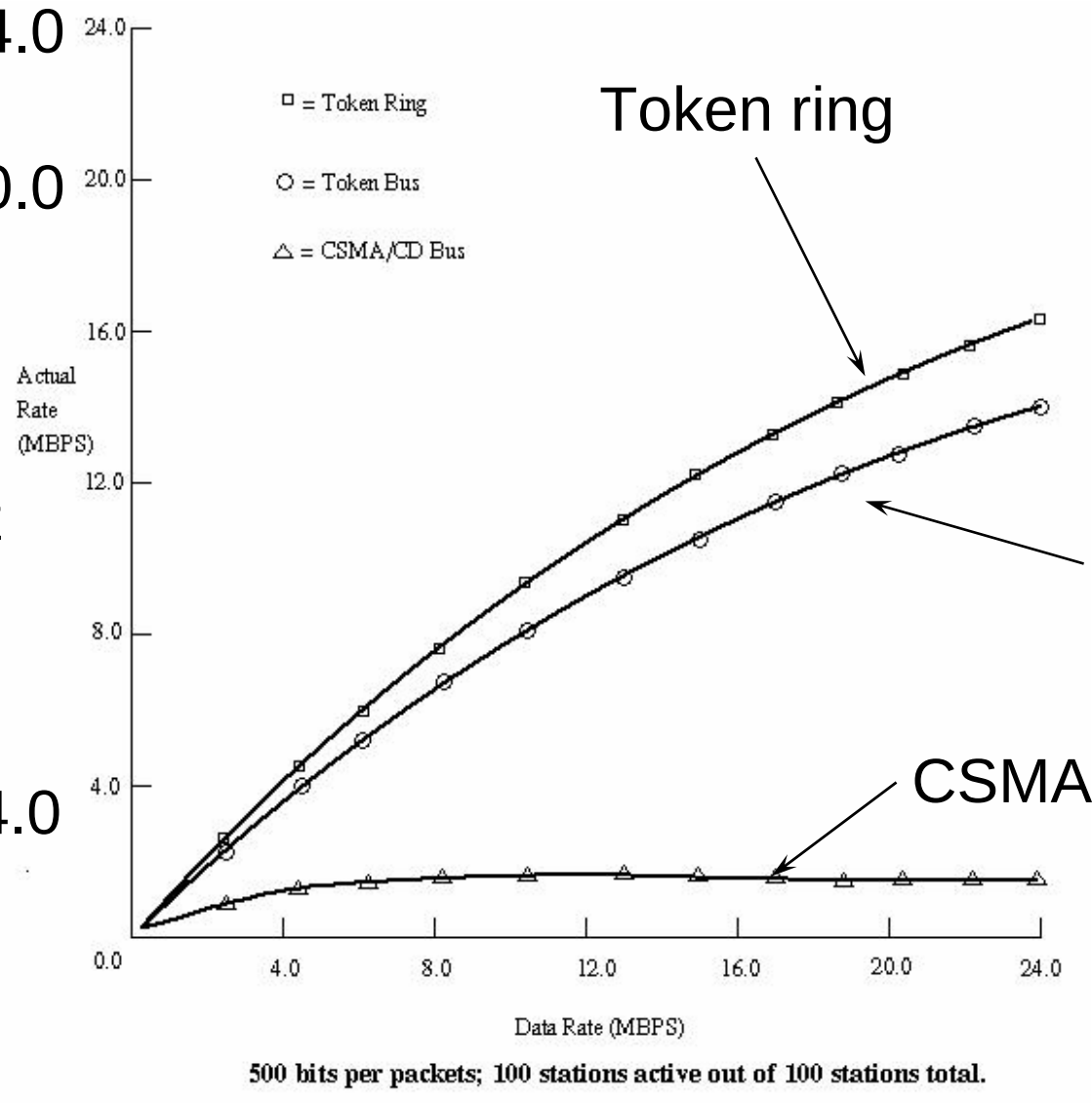


Other Features of Token Ring

- A user can designate a priority value so that only those users with this value or higher can use the network
- An active monitor exists which performs several tasks
  - Provides the master clock time to allow nodes to synchronize on the signal on the ring
  - Removal of zombie frames from the ring
  - Re-instate token that is lost or corrupted
  - Remove duplicate tokens
- Data Rate : 4-16 Mbps (look at Madge networks)

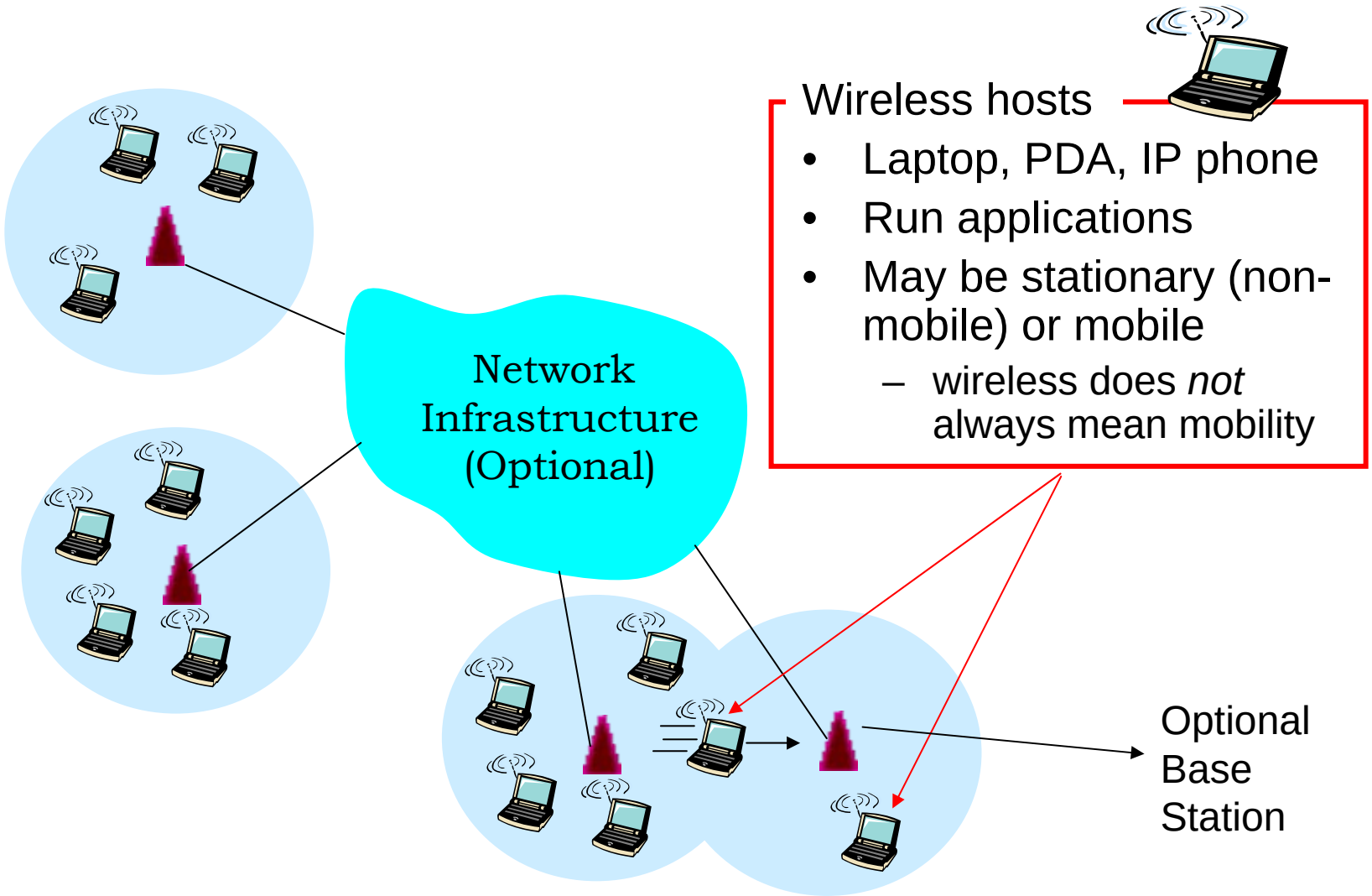
FDDI -Fiber Distributed Data Interface (ANSI X3T12)

- Similar to token ring, except that
  - FDDI runs on fiber-optic (token ring runs on twisted pair)
  - FDDI is based on IEEE 802.4 token bus rather than IEEE 802.5 token ring standard
    - In Token bus, token is explicitly transmitted to the “next” node
  - Has two counter-rotating rings i.e., data flow is in opposite direction to the other ring
    - Rings are independent: *primary* and *secondary*
    - During normal operation primary ring is used
    - During node failure, the primary ring wraps around secondary ring, creating a single ring and bypassing the failed node
  - All nodes participate equally in maintaining the FDDI ring
  - Data rate is : 100 Mbps

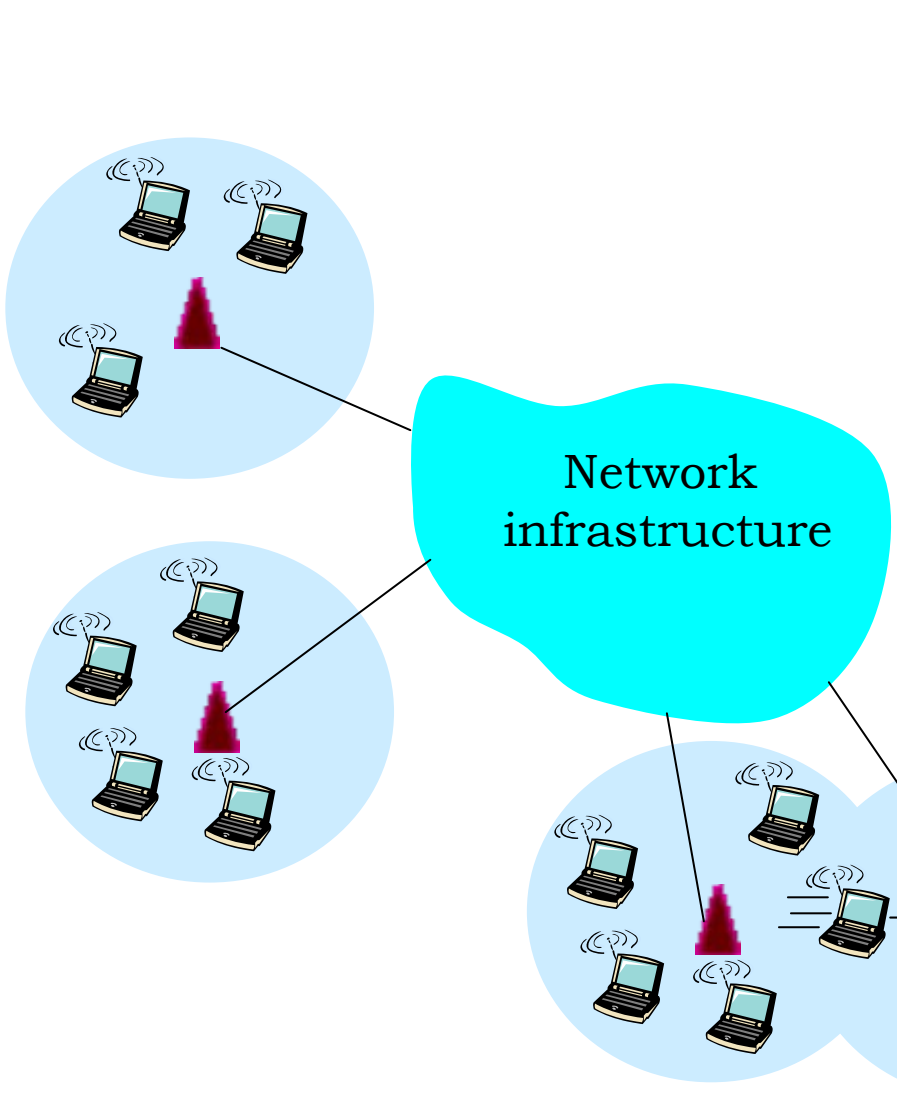


Non-contention based, deterministic access gives token ring/bus technologies better throughput

Elements of a Wireless Network


Wireless hosts
• Laptop, PDA, IP phone
• Run applications
• May be stationary (non-mobile) or mobile
– wireless does *not* always mean mobility
Network Infrastructure (Optional)
Optional Base Station

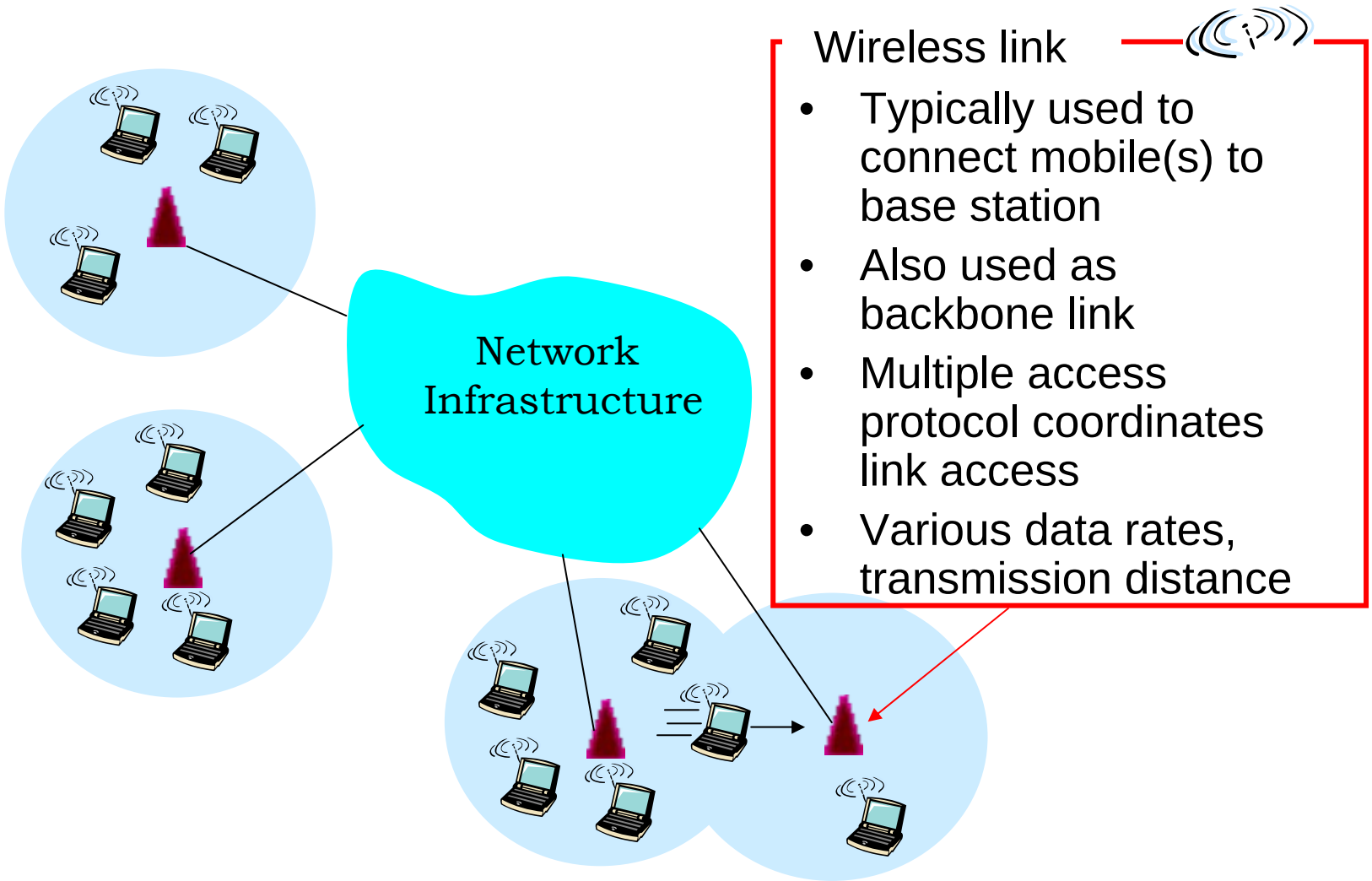
Elements of a Wireless Network



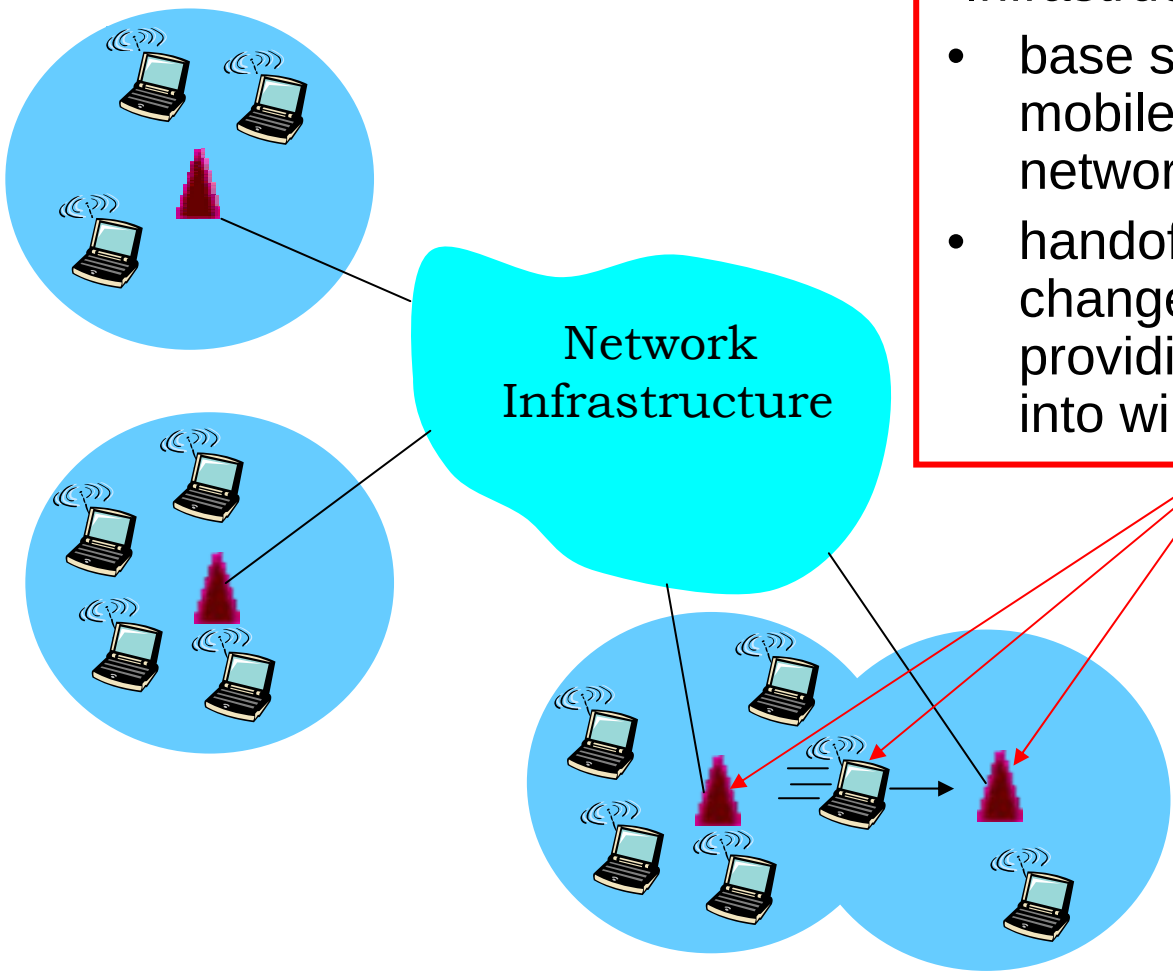
Base station

- Typically connected to wired network
- Relay - responsible for sending packets between wired network and wireless host(s) in its “area”
  - e.g., Cell towers
    802.11 access points

Elements of a Wireless Network


Wireless link
Typically used to connect mobile(s) to base station
Also used as backbone link
Multiple access protocol coordinates link access
Various data rates, transmission distance
Network Infrastructure

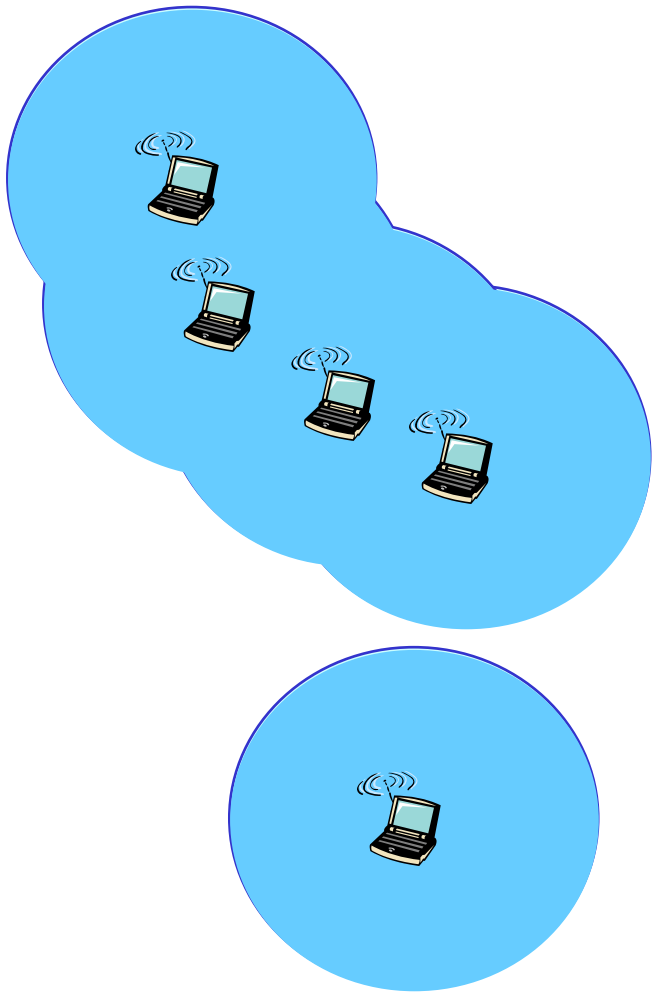
Elements of a wireless network



Infrastructure mode

- base station connects mobiles into wired network
- handoff: mobile changes base station providing connection into wired network

Elements of a wireless network



Ad hoc mode

- No base stations
- Nodes can only transmit to other nodes within link coverage
- Nodes organize themselves into a network: route among themselves

Wireless Link Characteristics

- Differences from wired link ….
  - Decreased signal strength: radio signal attenuates as it propagates through matter (path loss)
  - Interference from other sources: standardized wireless network frequencies (e.g., 2.4 GHz) shared by other devices (e.g., phone); devices (motors) interfere as well
  - Multipath propagation: radio signal reflects off objects ground, arriving ad destination at slightly different times

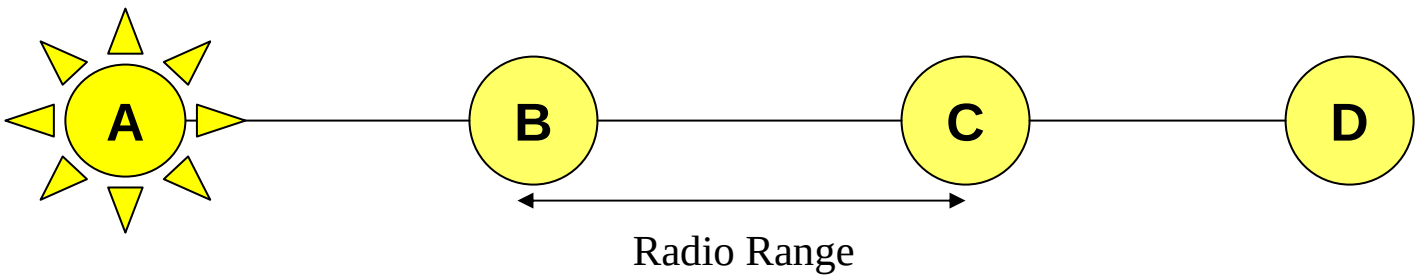
…. make communication across (even a point to point) wireless link much more “difficult”

Wireless LANs and CSMA

- Before transmitting, a sending station needs to know if there is activity around the receiver
  - Is CSMA/CD effective here?
- CSMA only tells if there is activity around the sending station
  - On guided (and shared) medium, only one transmission can take place at any give time
    - This is heard by all stations
  - When using wireless, multiple transmissions can occur simultaneously provided, that they all have different destinations and these destinations are “sufficiently” apart.
    - All transmissions need not be heard by all stations

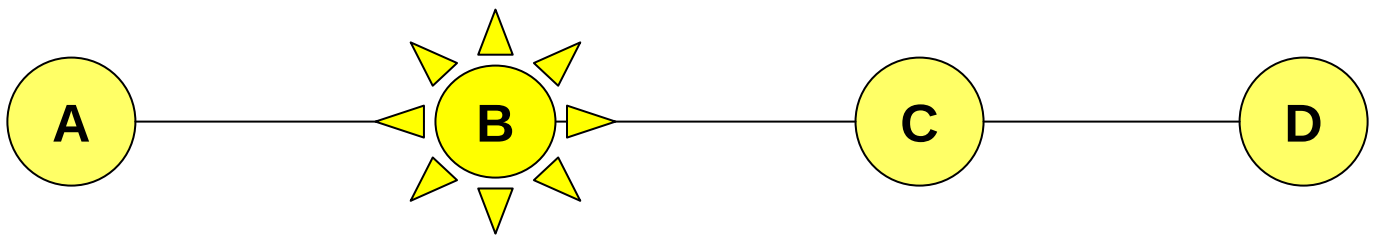
Hidden Terminal Problem

- Node **B** can communicate with both **A** and **C**
- **A** and **C** cannot hear each other
- When **A** transmits to **B**, **C** cannot detect the transmission using the *carrier sense* mechanism
- If **C** transmits, collision will occur at node **B**



Exposed Station Problem

- Station **B** is transmitting to station **A**
- Station **C** wanting to transmit to station **D**, would do the following
  - Sense the channel, and “falsely” determine that the channel is busy. It would then delay transmission till the channel is sensed idle.
- Had **C** transmitted, collision could possibly happened for **A**, but not for **D**.



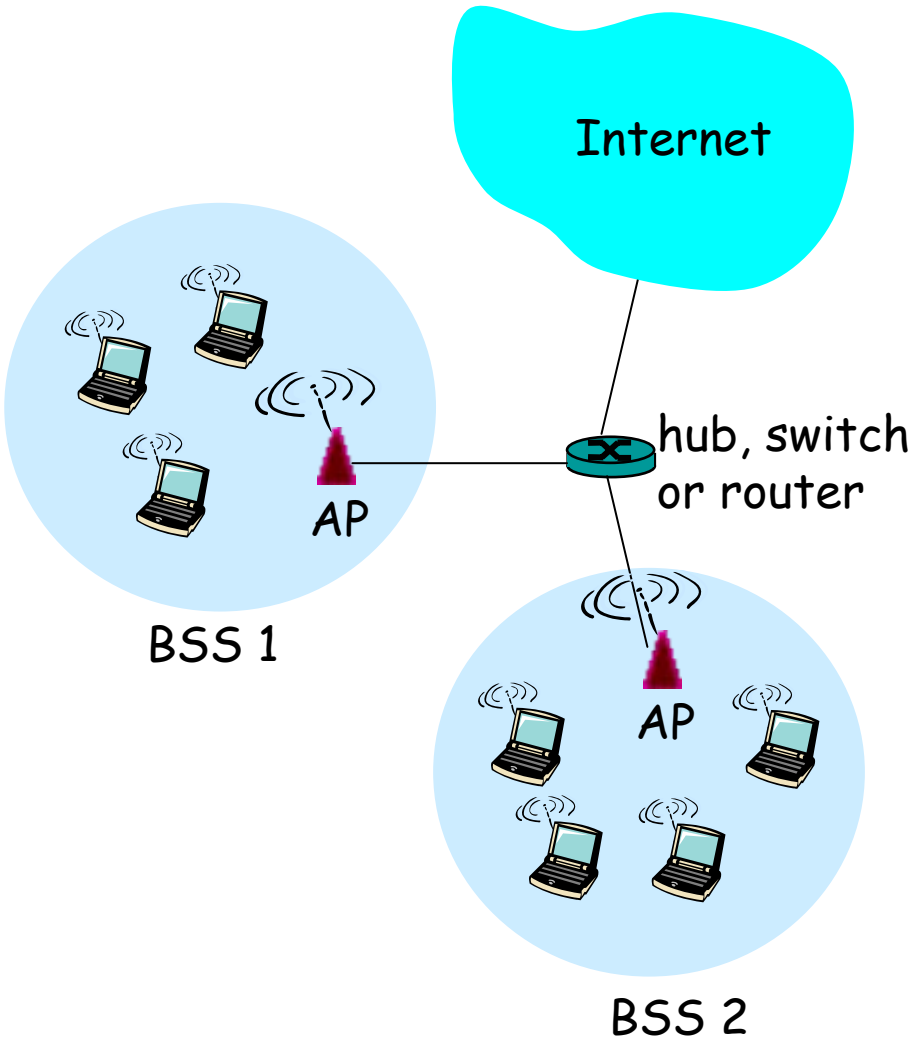
General Techniques for Medium Access in Wireless

- Use CSMA/CA :
  - sense channel for traffic
  - wait a random amount of time and start transmitting
  - Use acknowledgement as means to detect collisions
- Use channel reservation :
  - use CSMA/CA to detect idle channel
  - reserve channel with small packets thus, avoiding, hidden terminal and exposed node problems

IEEE 802.11 Wireless LAN

- 802.11b
  - 2.4-5 GHz unlicensed radio spectrum
  - up to 11 Mbps
  - direct sequence spread spectrum (DSSS) in physical layer
    - all hosts use same chipping code
  - widely deployed, using base stations
- 802.11a
  - 5-6 GHz range
  - up to 54 Mbps
- 802.11g
  - 2.4-5 GHz range
  - up to 54 Mbps
- All use CSMA/CA for multiple access
- All have base-station and ad-hoc network versions

802.11 LAN architecture



- Wireless host communicates with base station
  - base station = access point (AP)
- Basic Service Set (BSS) (aka “cell”) in infrastructure mode contains:
  - wireless hosts
  - access point (AP): base station
  - ad hoc mode: hosts only

802.11: Channels, association

- 802.11b: 2.4GHz-2.485GHz spectrum divided into 11 channels at different frequencies
  - AP admin chooses frequency for AP
  - interference possible: channel can be same as that chosen by neighboring AP!
- Host: must *associate* with an AP
  - scans channels, listening for *beacon frames* containing AP's name (SSID) and MAC address
  - selects AP to associate with
  - may perform authentication
  - will typically run DHCP to get IP address in AP's subnet

802.11 Modes of Operation

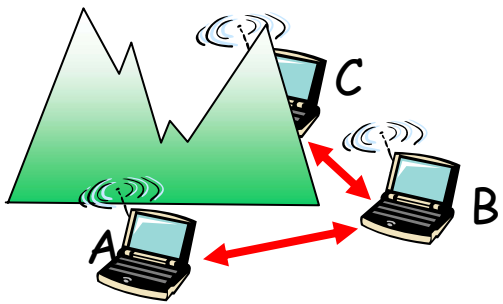
- Most wireless devices cannot transmit and listen at the same time on a single frequency, thus CSMA/CD is not used
- The supported modes of operation are:
  - DCF, Distributed Coordination Function
    - No central controller; just like Ethernet
    - Protocols used are:
      - CSMA/CA (CSMA with Collision Avoidance)
      - CSMA/CA with virtual channel
  - PCF, Point Coordination Function
    - The base station controls all activities
    - Prioritized transmissions possible

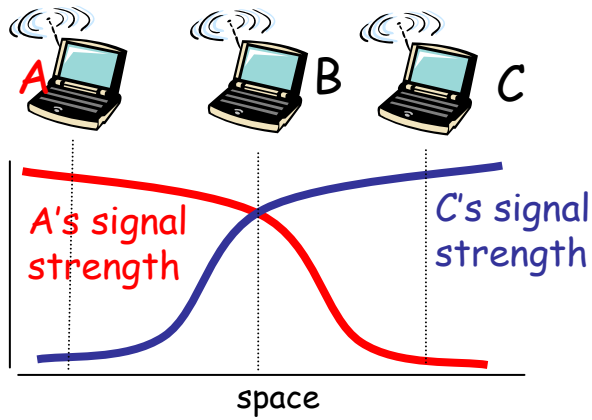
DCF

- DCF, Distributed Coordination Function
  - No central controller; just like Ethernet
  - Protocols used are:
    - CSMA/CA (CSMA with Collision Avoidance)
      - Sense the channel before transmitting. If idle, transmits. It does not sense the channel while transmitting
      - Waits DIFS+RandomTime before transmitting
      - Receiver waits SIFS time before acknowledging
      - Using duration field in 802.11 frame other nodes backoff this much amount of time (NAV)
    - CSMA/CA with virtual channel
      - Perform channel reservation
      - RTS alerts and indicates duration of frame for sender's range
      - CTS alerts and indicates duration of frame for receiver's range

IEEE 802.11: Medium Access

- Avoid collisions: 2^+ nodes transmitting at same time
- 802.11: CSMA - sense before transmitting
  - don't collide with ongoing transmission by other node
- 802.11: *no* collision detection!
  - difficult to receive (sense collisions) when transmitting due to weak received signals (fading)
  - can't sense all collisions in any case: hidden terminal, fading
  - goal: *avoid collisions:* CSMA/CA





IEEE 802.11 MAC Protocol: CSMA/CA

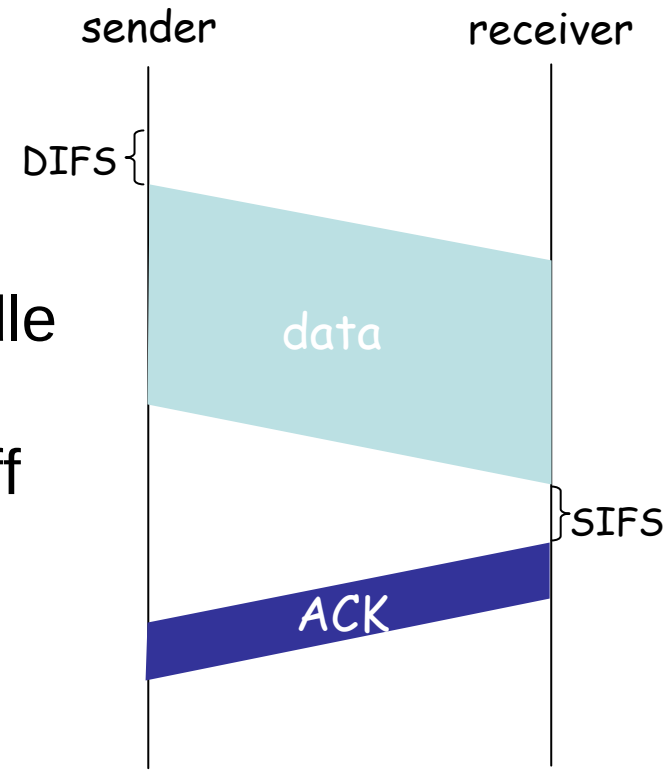
802.11 sender

1 if sense channel idle for **DIFS** then
    transmit entire frame (no CD)

2 if sense channel busy then
    start random backoff time
    timer counts down while channel idle
    transmit when timer expires
    if no ACK, increase random backoff interval, repeat 2

802.11 receiver

- if frame received OK
    return ACK after **SIFS** (ACK needed due to hidden terminal problem)



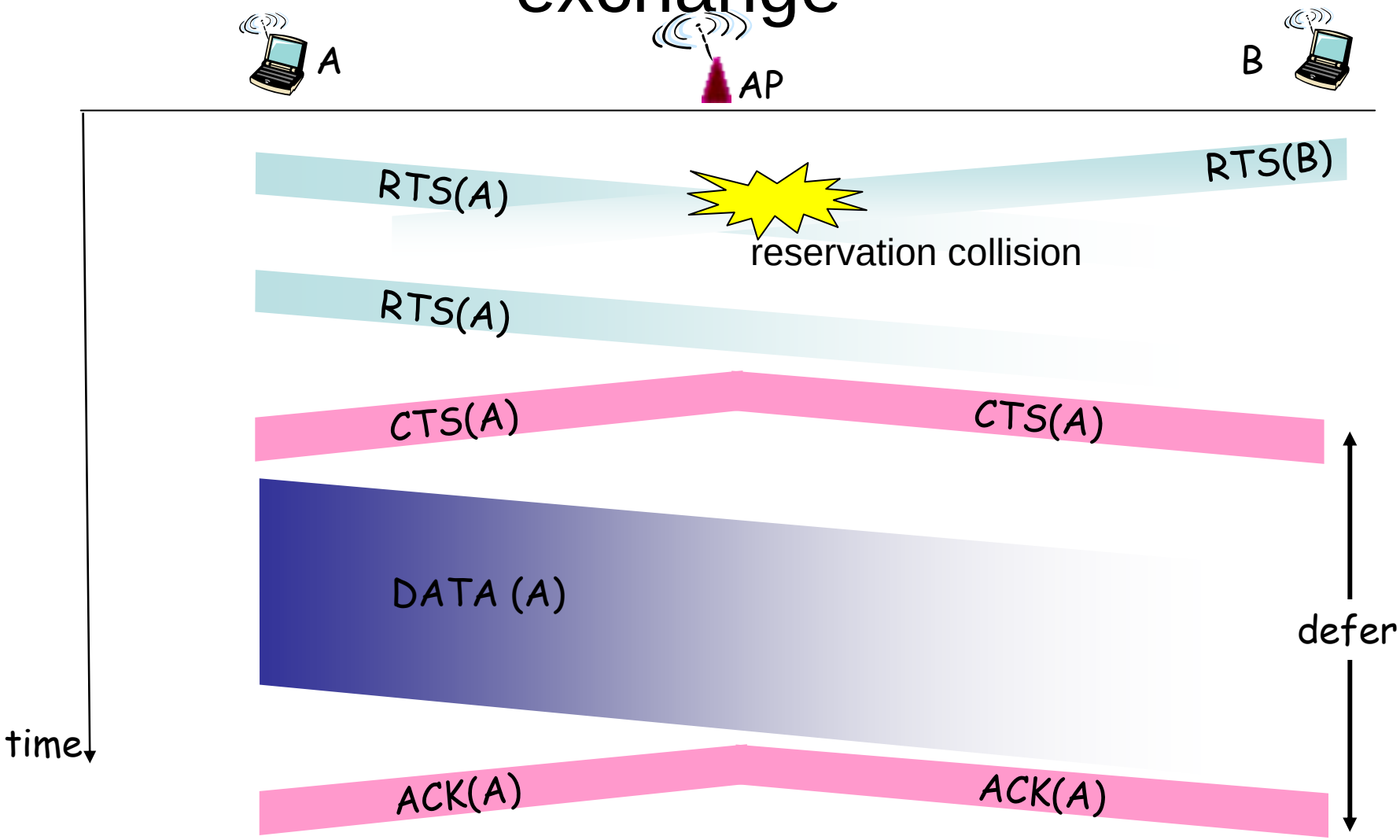
Avoiding Collisions (more)

Idea: allow sender to "reserve" channel rather than random access of data frames: avoid collisions of long data frames

- sender first transmits *small* request-to-send (RTS) packets to BS using CSMA
  - RTSs may still collide with each other (but they're short)
- BS broadcasts clear-to-send CTS in response to RTS
- RTS heard by all nodes
  - sender transmits data frame
  - other stations defer transmissions

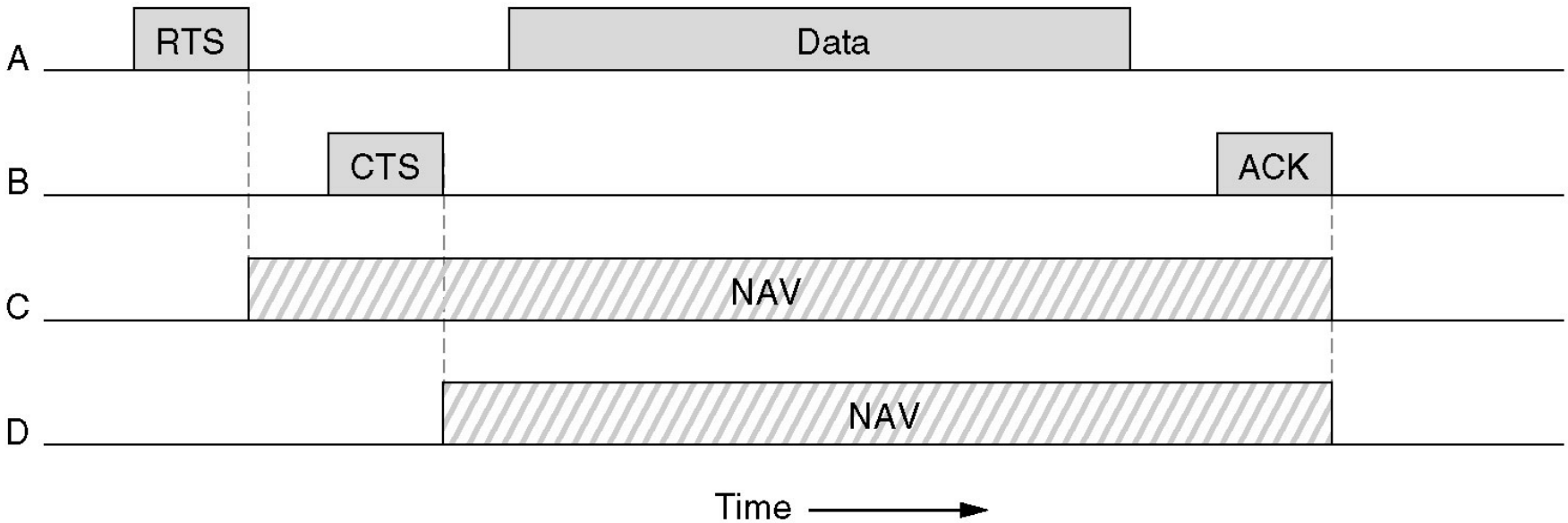
Avoid data frame collisions completely using small reservation packets!

Collision Avoidance: RTS-CTS exchange



The 802.11 MAC Protocol…

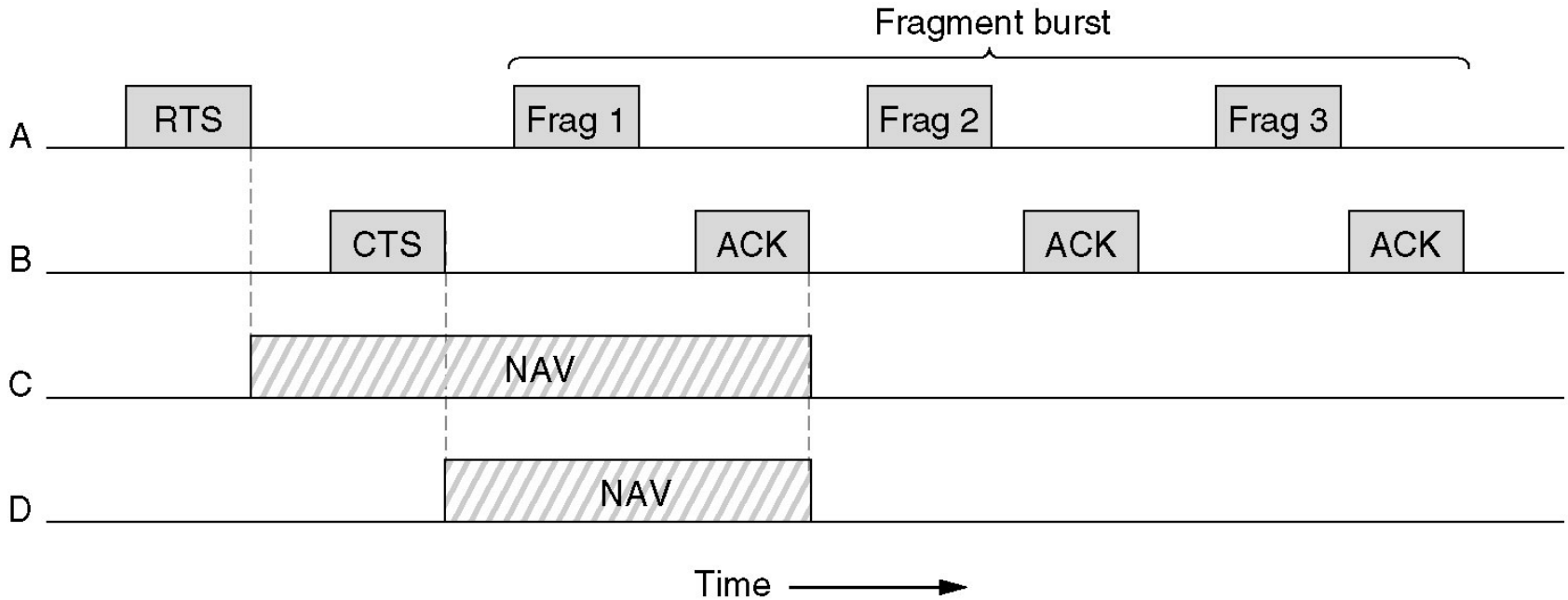
- The use of virtual channel sensing using CSMA/CA
  - RTS/CTS contain the period of transaction (packet+ack transmission length)
  - C is within range of A –waits for the data length in RTS
  - D is not within range of A –wait for the data length in CTS



NAV = Network Allocation Vector, an internal reminder to keep quiet for a certain period of time

The 802.11 MAC Protocol…

- NAV for a particular node depends on which frame it is able to hear
  - Nodes in sender's range have longer NAV compared to nodes in receiver range



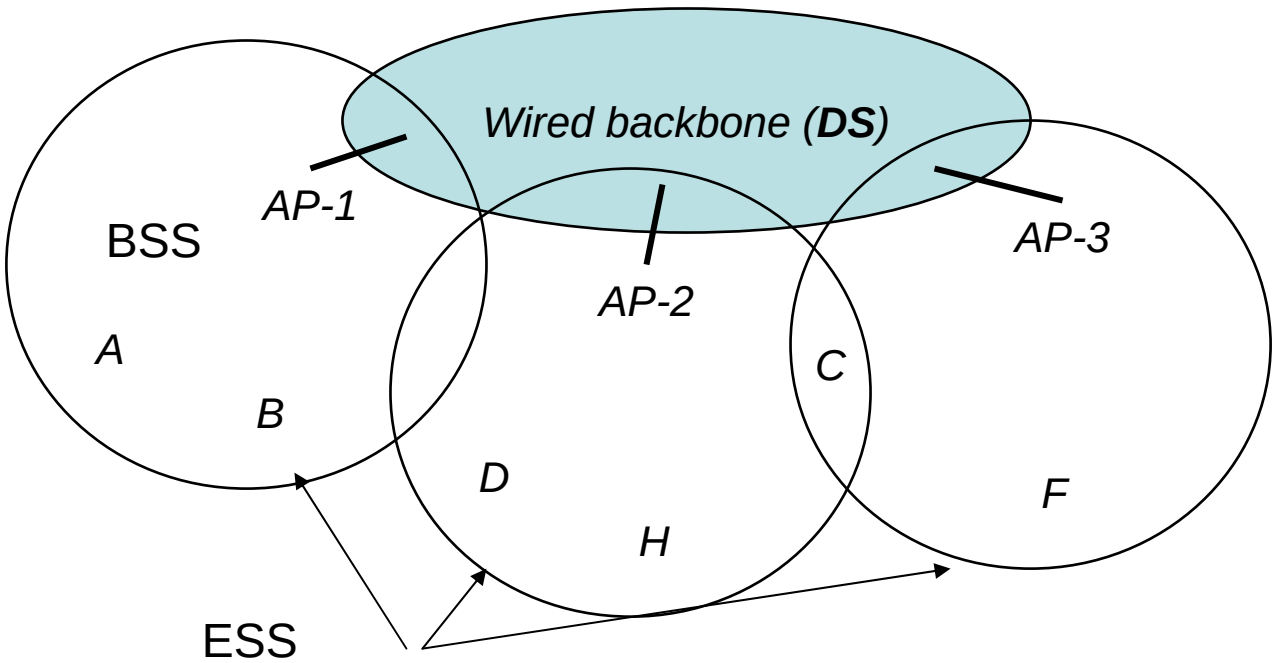
MACA+ Acknowledgement = MACAW (MACA for Wireless)

PCF: Point Coordination Function

- The base station polls the other stations asking if they have any frames to transmit, and co-ordinates transmissions, avoiding collisions :
  - This allows base station to allow some high priority/time-bound applications to gain access to the channel
  - In PCF mode : the base station broadcasts a beacon frame 10 to 100 times per second, providing system parameters, and giving opportunities to the prioritized stations to sign up.
  - In between (prioritized transmissions), the station can switch to DCF and allow other nodes to continue transmission (assuming there is sufficient gap between the prioritized transmissions)

Extending Wireless Network

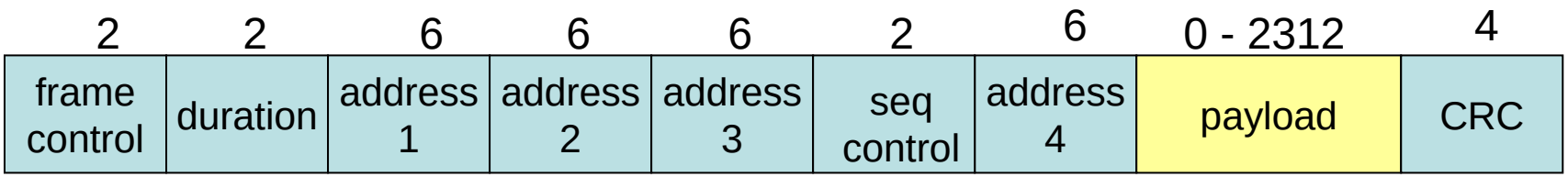
- Some nodes are allowed to *roam* (e.g., your laptop)
- Access points (AP) or base stations, are connected to a wired network infrastructure to extend the network
- Wired infrastructure can be a backbone, such as Ethernet or Ring, called Distribution System (DS)



Extending Wireless Network…

- Each roaming station must be associated with a single AP. This can be done:
  - Via active scanning,
    - The node sends a *Probe* frame
    - All APs within the reach reply with a Probe Response
    - The node select one AP and sends that AP an Association Request
    - The AP replies with an Association Response frame
  - In response to a *beacon frame* issued by the APs
    - The APs broadcasts a beacon frame 10 to 100 times per second, providing systems parameters, and giving opportunities to the stations to sign up.
- The AP creates an association for this node and informs other APs, only then can this node start sending and receiving data

802.11 Frame: Addressing



Address 1: MAC address of wireless host or AP to receive this frame

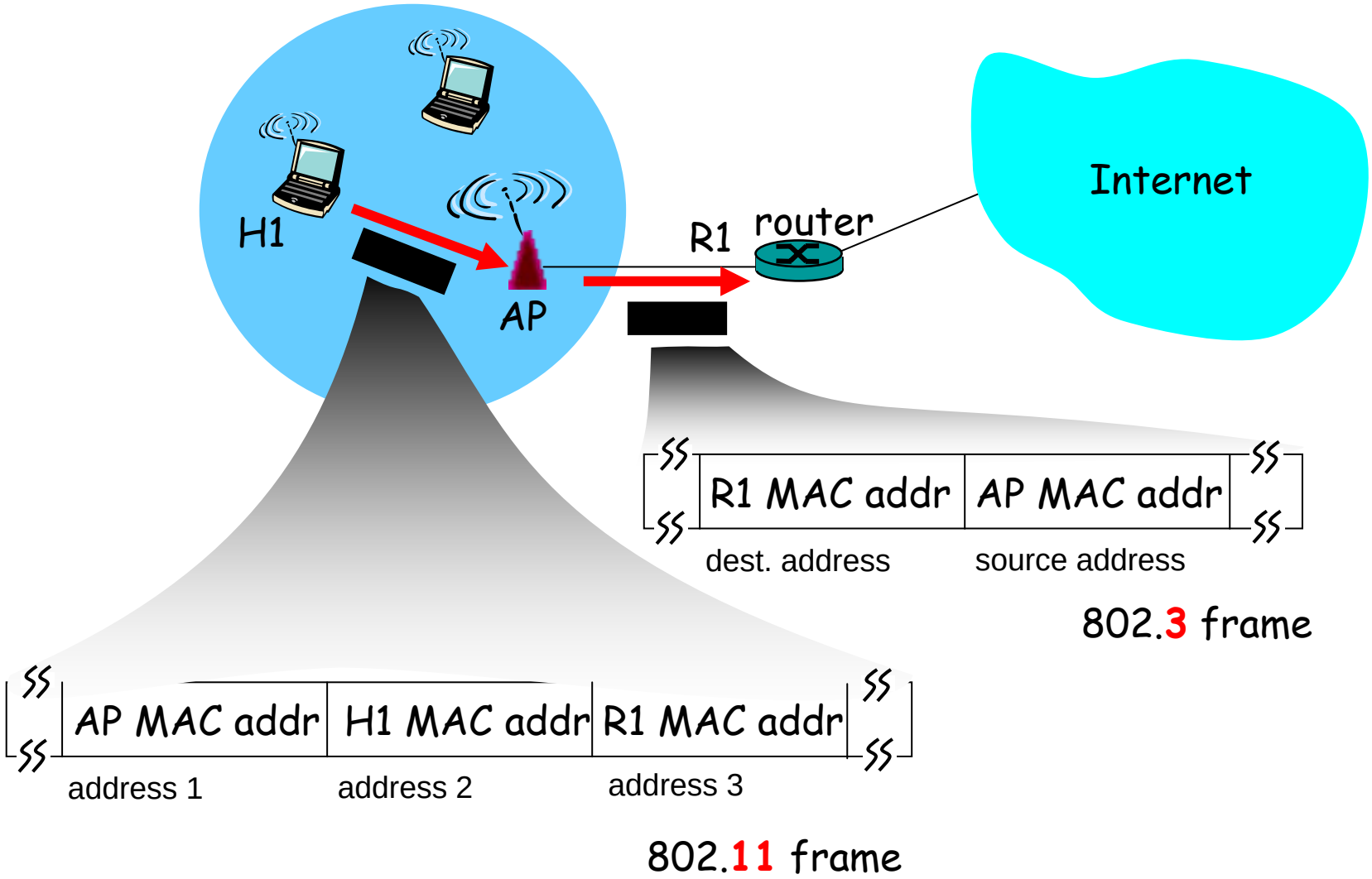
Address 2: MAC address of wireless host or AP transmitting this frame

Address 3: MAC address of router interface to which AP is attached

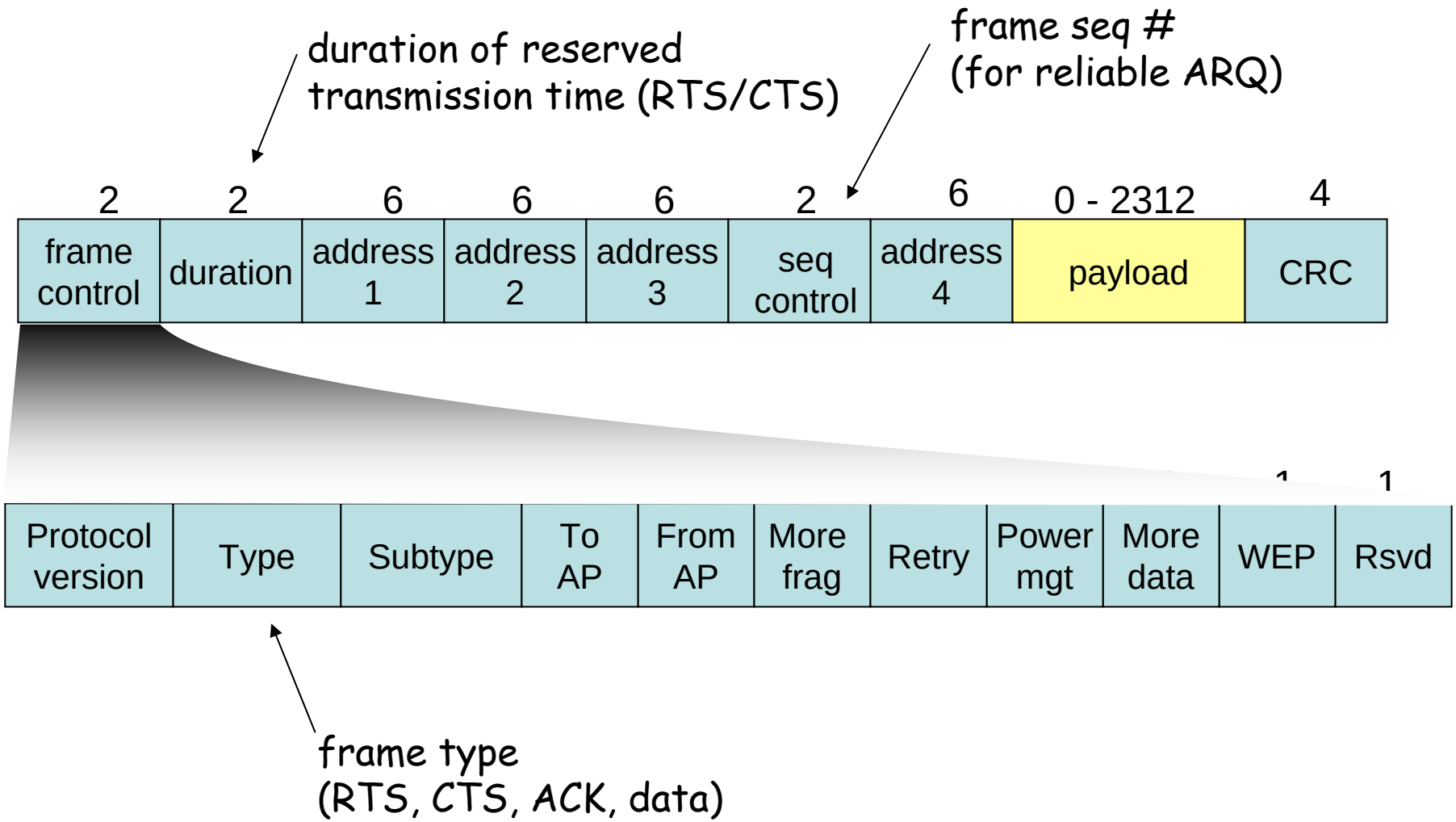
Address 4: used only in ad hoc mode

Frame needs to contain sufficient information to send it across the DS to any node that is reachable in the DS

802.11 frame: addressing



802.11 frame: more



802.11 Services

- Distribution Services (inter-cell)
  - Association
    - When a station enters the range of a base station
  - Disassociation
    - Breaking connection
  - Re-association
    - Reconnecting
  - Distribution
    - Frame routing; local or remote destination?
  - Integration
    - Forwarding frame to a non-802.11 network

802.11 Services…

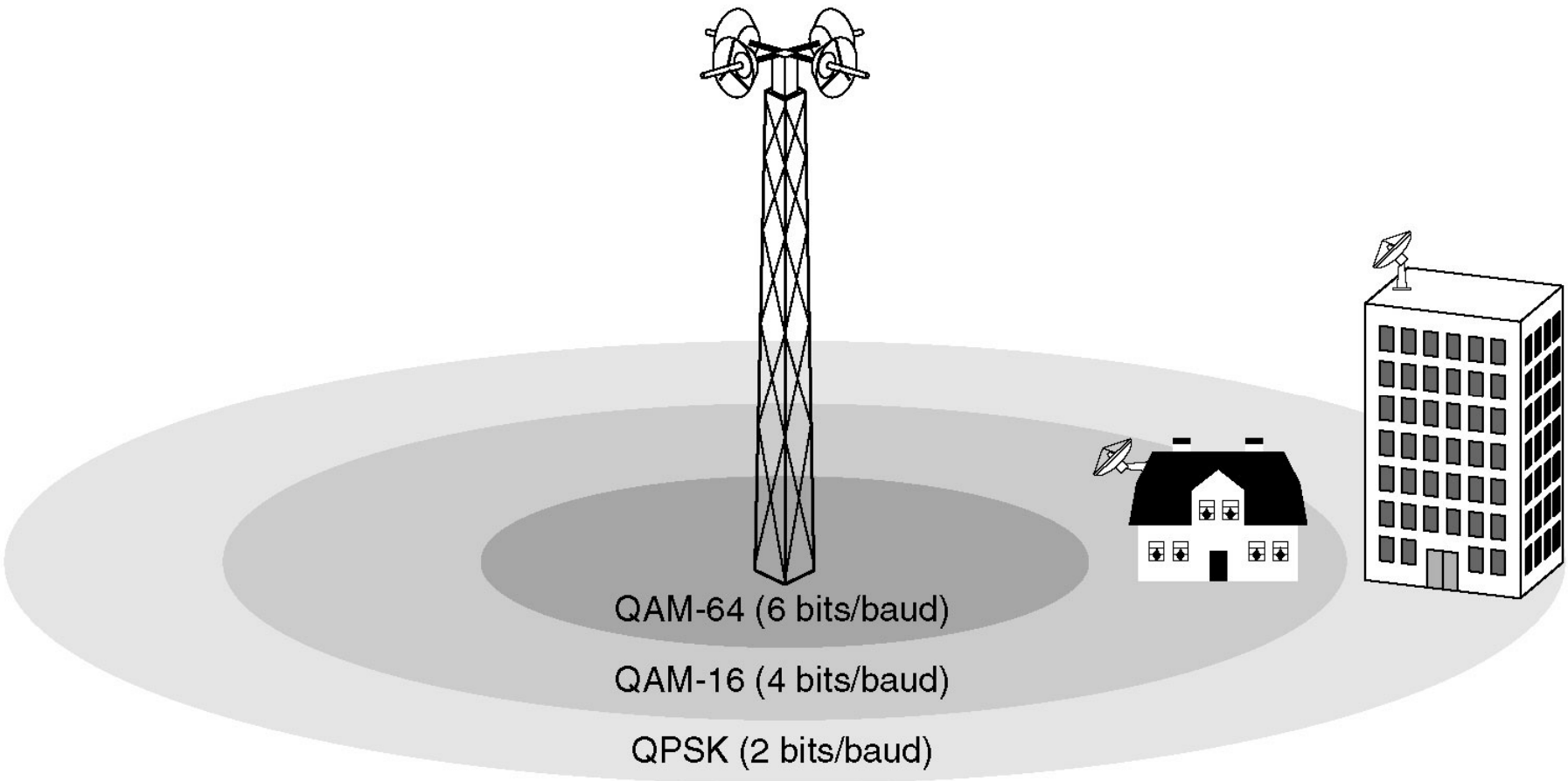
- Station services (Intra-cell)
  - Authentication
    - After association, a challenge/response interaction is done
  - De-authentication
  - Privacy
    - Using encryption/decryption (Wired equivalent privacy WEP)
  - Data Delivery

Wi-MAX (802.16)

- Worldwide Interoperability for Microwave Access
- Originally conceived as the “last-mile” technology
- Client systems, called *subscriber stations*, are systems that multiplex all the communication services
  - Mainly clients are not mobile as in 802.11 networks
  - E.g., A campus that combines all requests from its individual stations as single client
- Covers up to 30 miles with a data rate of up to 150 Mbps

The 802.16 Physical Layer

- The 802.16 transmission environment.



802.16 Physical Layer

- Operates in the 10-to-66 GHz frequency range.
  - 802.16a will operate in the 2-to-11 GHz band
  - 802.16b will operate in the 5 GHz ISM band
- Employs three different modulation schemes
  - QAM-64, with 6 bits/baud, achieving 150 Mbps
  - QAM-16, with 4 bits/baud, achieving 100 Mbps
  - QPSK, with 2 bits/baud, achieving 50 Mbps
    - The farther from the base, the lower the data rate

Other Popular Wireless

- Bluetooth : Aimed to eliminate wires between personal networked devices
  - E.g., data transfer between a PDA and a cell phone
- UWD : provides high speed bandwidth for local, (non-walled) networks in the range of 480-1GBps Mbps
- Gigabit wireless: provides gigabit speeds in for moving high volume of data at 2-10Gbps
  - Can copy a DVD movie in 2 seconds to a remote device